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Design, Development and Manufacturing of Tangential Feed for a CNC Gear Hobbing Machine

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Abstract - *Present world is heading towards automation for accurate production. CNC hobbing is an excellent technique use for production of gears with high accuracy. If industries are using conventional gear hobbing process then there is a need to replace it with a CNC gear hobbing by using NC codes and program logic unit. Hence to achieve higher and economical production. It is so convenient and easier than any other process. Gear hobbing is a generating process. The term generating refers to the fact that the gear tooth form cut is not the conjugate form of the cutting tool, the hob. By using fixture, ball screw, servo motors we improve it. Backlash error eradication as well as high work piece job accuracy has been achieved due to implementation of this ball screw system for CNC Machine as well as carried out various design validation processes to provide high result. After transformation in gear hobbing machine the test results show that computerized numerical control transformation which helps to improve efficiency and life span of machine and make effortless machine.*

Key Words: *Gear hobbing machine, ball screw, backlash error, servo motors*

1. Introduction

In today's automotive world and by considering improvement in technology each and every core based industry need to improve the performance of company and in this automation world CNC is one the best and efficient technology is glowing. It's exactly economical but it's a time saving machine as compared to old conventional machine which makes it more useful than any other manufacturing process. While it will be good to do retro activation in machine to make it faster and versatile. Retro activation is define add or fit the component else accessory to something that did not have it when it was manufactured. basically it is refitting procces.it means we are going to update the system with a new technology to improve the performance by exchanging old technology and add the sensors, motors and every important thing that makes it better with increase in efficiency.so because of retrofitting we get many advantages which introduce new technology[1].

Hobbing is most popular method of cutting teeth on gear which produce helical and spur gear this method have anticipated benefits than others include lower cost investment. Hobbing CNC Having a hobber to cut the teeth on gear we can give any feed to gear as per the type of gear which is to be manufactured [2]. Generally CNC hobbing have bed and column having all setup is having on it. Where with the help of hob we can cut the desirable type of gear by using programing we can cut teeth in angle also and this is so quick as compared to conventional machining process. The opportunity to manufacture gears to a high quality are much improved with CNC Controlled hobbing Machines, Since they have reduced transmission error reduced set-up time, better reliability, and thus reduced cost. New generation machines are based are based on Computer numerical control where the axes are synchronized with electronic gear box. There are both hobbing machines available automated and non-automated [3].

Types of Feed

Types of feed in a CNC type Gear Hobbing Machines are:

a. Axial Feed
b. Radial Feed

Different types of axis in a CNC gear hobbing machine are:

a. Spindle rotation (clockwise and anti-clockwise)
b. Table rotation (clockwise and anti-clockwise)
c. Axial type
d. Radial type
e. Hob shifting (Tangential)
f. Swelling axis (angle for helical gear)

So this Study will include the modeling of tangential feed drive in an Industrial CNC Gear Hobbing Machine.

Design Methodology

- Selection of Ball Screw
- Selection of Bearings
- Selection of Bearing Housing
- Assembly

Literature Survey

Delvadiya et al. said that Instead of buying a new CNC gear hobbing machine it is more convenient to convert the old conventional machine into CNC by programmable logical controllers and servo mechanisms. This will lead to higher productivity and as well as more economic.

Sethi et al. said that as to increase the productivity it is necessary to reduce the time required for the fixture settings, and to design a common fixture which can be used for all the gears. This will depend on design expertise and there optimal solution which they provides.

Kulkarni et al. said that as there is demand for higher productivity and also tolerances should be tight it requires machine tools which are faster and very accurate at feed drive systems. As ball screw drive systems are used majority of machines, this system is tested several time. And it is used vastly because of its low cost and higher accuracy.

2. Principle of PA300 Gear Hobbing

The PA300 CNC gear hobbing machine was originally a conventional gear cutting machine. **PA300** having two skew spindle, which is mounted with a blank work piece and another with the hob.

The conventional hob is made of high- speed steel which is hardened and may be ground on the form. It can be like to an involute worm provided with flutes usually at right angles to helix. It also having lead screw, lead screw is known as power screw which used to translate turning or linear motion but it having more friction energy losses as compared to other systems. On other hand it having large load carrying capacity, minimum no. of parts and most are self- locking apart from this they are not so efficient so due to less efficiency they are not suitable to be used in continuous power transmission applications. They are also having high degree of friction on the threads, which can wear out threads quickly. And conventional hobbing drives with one main motor with working gear, hydraulic system, working table, cooling. The worktable is mounted on a very big bearing surface to boost cutting forces produce by hob.

The arrangement is suitable for conventional hobbing. Hob shifting regulator is there. Limit switches use as a signal switches. An electric pump provides the coolant to the hob during cutting. Front panel of machine, a switch panel is fitted. Principle behind hobbing in which continuous progression of gear cutting is going in a mesh with hob, progressively cutting all the teeth at a constant time. Because of rotation of hob desired type of gear with no. of teeth could produce. Gear should be adjusted with transmission relation therefore the teeth no. of created gears. Once the gear is modified, the modification of gear is calculated and manufactured. After that if error will occur it will fix it. The arrangement and model of PA300 is shown below.

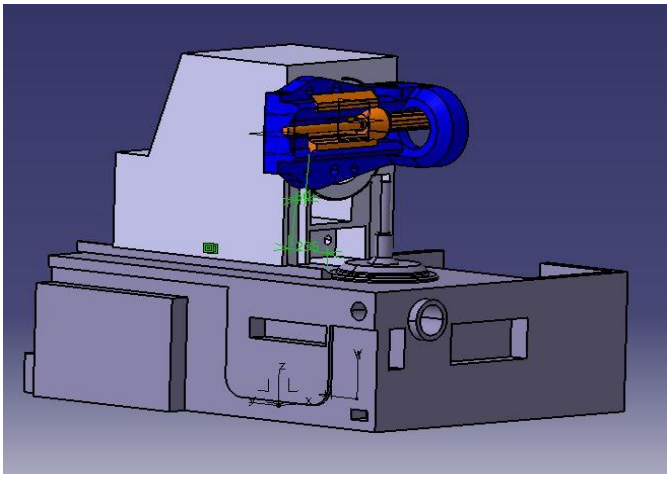

Fig -1: Gear Hobbing Machine Catia Model (PA300)

3. Design of PA300 Gear Hobbing

Characteristics of ball screw are as follows:

a. More mechanical efficiency: The forces which is used to rotate the screw shaft it can also be used to move the nut of ball screw.
b. Less in wear: As there is a rolling contact wear is very less than that of sliding contact. This tends to less rotation accuracy.
c. Less in tear: Ball screws can also move better in very low speed application. Thus it can be used in high load applications easily [4].

Maximum stroke of column: 300 mm
Minimum stroke of column: 50 mm
Total effective stroke of the column: 300 – 50 = 250 mm
Nut length = 200 mm
Clearance distance = 10 mm
Total length of Ball screw = 250 + 190 + 10 = 450 mm
Take total Safe length = 460 mm
Length of Total shaft = 460mm.

The above dimensions of ball screw are shown in below figure.

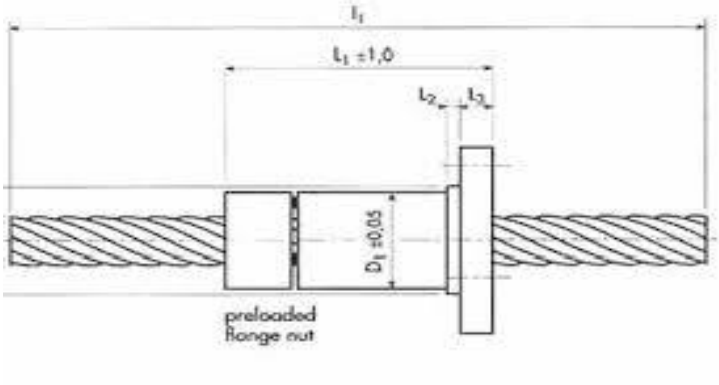

Fig -2: Shaft Design Layout

Bearings

The bearing details given by the manufacture was BS40M90. Hence we have done the calculations to check the suitability.

Selection criterion of bearing is as follows:

a. Available Space
b. Load
c. Speed and Friction
d. Misalignment
e. Temperature
f. Precision
g. Stiffness
h. Mounting and Dismounting
i. Integral sealing
j. Cost and Availability [5][6]

Machine Specifications Given By Manufacturer were as follows:

a. Power Transmitted : 20 KW
b. Speed of motor shaft: 1000 rpm
c. Shaft diameter : 45 mm
d. Type of Load : Axial and Radial

Types of Loads Acting On Bearing:
Axial Load: Due to Column and Hob Head Weight
Radial Load: Is Almost Negligible
Fa = 2600 N.
Fr = 110 N.
Internal Diameter of Bearing: 45 mm.
Outer Diameter of Bearing: 95 mm.

Thickness (b) = 25 mm

Basic static Load capacity (C0) = 92000 N
Basic dynamic load capacity(C) = 61000 N

Load application factor: Ka = 1.05 for timing belt drive [6].

Bearing calculation validation is as follows.

Fa/C0 = 2600/92000 = 0.02826
Factor X = 0.56
Factor Y = 1.875

Equivalent dynamic load is:
Pe = (X*Fr +Y*Fa)* Ka
Pe = 5183.43N

Calculating life of bearing according to type of application

L10h = 24000 hrs
L10 = L10h*60 *N/106
L10 = 24000*60*1000/106
L10 = 1400 m rev.

Required dynamic load capacity (Cr):
L10 = (Cr/Pe) ^a where
a = 3, for ball bearing

L10 = (Cr/Pe)^a
1400 = Cr/5167.58^3
Cr= 57986.45N.
If C > Cr, Bearing selected is suitable.

Here c>cr. Hence selected bearing is suitable for application [7].

Bearing Housing

- Checking of the housing is done by checking the conversion of rotary motion to the linear motion.
- Also we should have to fix the shaft to check whether it is not moving with the column. If it is moving then it will create the backlash error.
- Then with considering the available length of column and bearing housing mount design of the bearing housing started.
- After all the procedures and considerations we are done with design of bearing housing.

Design process of bearing housing is as follows:

- Very firstly we have assembled the column on the bed. Then we inserted the screw shaft in the column. At that time there was 250mm size left on the bed for the bearing housing.
- As per design considerations for the proper and perfect support we have selected odd number of bearings.
- The placing of the bearing, preload caps and the spacers is as shown in the fig-3 which illustrates the internal structure of the bearing housing.
- The thickness of the preload cap as per issued design was 15mm followed by a 25mm thick bearing.
- As per our ID and OD of the shaft we placed the spacers of 10mm thickness. And in-between the spacer we have inserted the second and third bearing.
- As mentioned above the number of bearing selected was odd the reason behind this was there is restricted space in the bearing housing else we could have selected even number of bearings.
- As our shaft is 150mm long we designed the internal structure of bearing housing of 125mm. next to that we inserted the crown nut and a quarter pin to hold both bearings as well as crown nut. The main advantage of the quarter pin is it avoids the slippage.
- As per our calculations and the design we manufactured the ball screw from the outside manufacturer. The total length of shaft as mentioned in ball screw calculations was 460mm and the mounting in the bearing housing is of 150mm. The nut length as per the manufacturers catalog was 200mm.
- The structure inside of the bearing housing is shown in the figure.

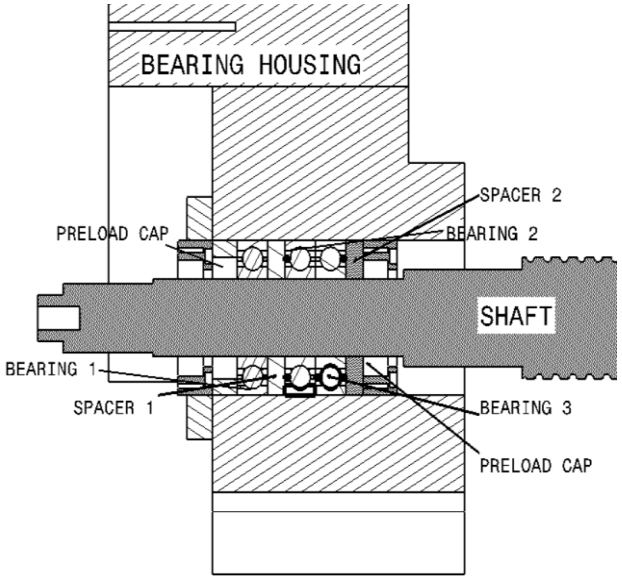

Fig -3: Inner Bearing Housing Structure

- As the calculations are validated bearing was selected we started with the design of the earing housing in the CATIA. The area of 280*280 was taken under consideration while designing on software. Material of bearing as mentioned in the catalog was FG260.
- EN-8 is the material which was used by the manufacturer. This is strengthened than screw shaft (56HRC). Ii was also case hardened from 1.3mm to 1.6mm. As the manufacturing process of the bearing housing is done we have done assembly and mounting of housing.
- After this all manufacturing and assembly processes we have ordered our selected bearing which is screw type support bearing from the IBC. And finally we have designed and developed the tangential feed system for the machine PA-300.

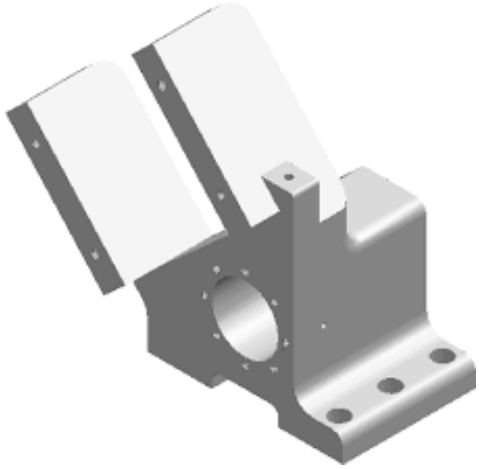

Fig -4: Bearing Housing Model

4. Manufacturing and Assembly

The following model shows the manufactured tangential feed system.

- **Ball screw and bearings**

  As per the design and the calculations the final bearings and the ball screw was selected. This selected ball screw and bearings we ordered from outside vendor [8].
- **Bearing housing**

  The material used for this was grey iron casting (FG260).
- **Other parts**

  This is mainly consists of spacers and preloading caps. It is generally made up of toughened steel (EN8) [9].

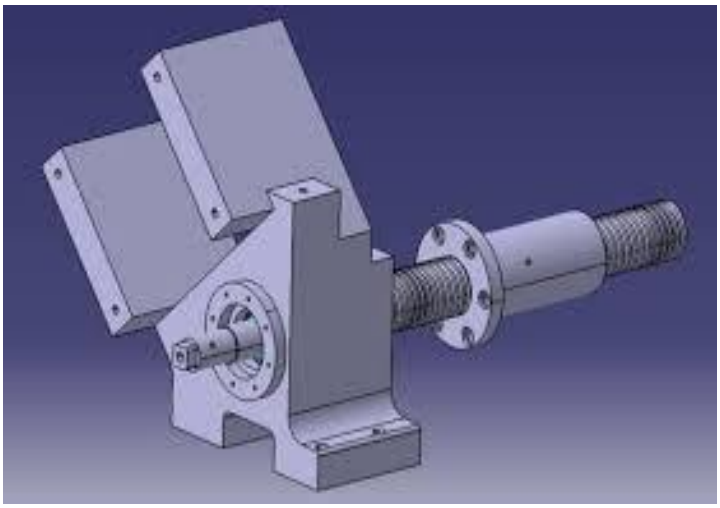

Fig -5: Tangential Feed Model

Pre-Assembly and Alignment is as follows:

- In this process column is mounted on the bed and ball screw system on the column.
- The male guide way of the bed must match with the female guide way of the column.

a. Scraping: - These processes helped in filling up minute gaps present over the surface and provide a flat surface.
b. Lapping: - It is a conventional process done by workers hand movement. It consists of rubbing of two surfaces together to achieve higher accuracy of surface finish.

Final assembly process is as follows:

After the alignment process, we mount the bearing housing. We insert the bearings and spacer into the structure. Preloading caps are been mounted such as to preload the bearings and eradicate the back lash error. To protect the balls in the ball screw from the dust particles balls are kept

in the closed enclosure of grease. This enclosure is generally sealed.

Limit scale is used to check the accuracy of stroke and notify the user via FANUC coding.

As the machine is CNC we have used several limit switches to define the initial stroke of column.

After the housing is been mounted over, the machine is run and carry out about 65-75 jobs over. This helps us to find the accuracy of the entire machine.

Fig 6- Final Tangential Assembly

5. CONCLUSIONS

We have designed a Tangential feed system for a CNC Recirculating ball screw system to convert the rotary system into a linear system. We carried various design iterations over the bearing housing in order to minimize the motor vibrations and hold the shaft. Using a lead screw causes high back lash error which was eradicated by using a Recirculating ball screw system. We successfully reduced the back lash error from 0.5mm to 3microns.

Thus to achieve a higher mechanical efficiency and low wear and tear, a Recirculating ball screw system is been used in a Gear hobbing Machine. We turned this conventional hobbing machine to a CNC gear hobbing machine. Hence we have achieved and successfully developed a highly optimized, backlash error free CNC hobbing machine which will provide greater accuracy as compared to the conventional system.

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